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CHANGES IN VISUAL DEPTH PERCEPTION WITH THE WEARING OF CONTACT LENS

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ABSTRACT

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OBJECT

To test the hypotheses that changes in stereoptic acuity and spatial localization take place when contact lenses are worn.

To evaluate four types of contact lenses relative to spectacles on the basis of the stereoptic acuity and spatial localization performances of several subjects.

RESULTS AND CONCLUSIONS

Data for spectacles and each of three types of contact lenses at each of six times of measurement during a 460-minute wearing period were analyzed for eight subjects. (The data of one type of contact lens were not analyzed because only one of the eight subjects was able to wear the lenses for the duration of the test period.) The technique of analysis of variance was used.

A stereoptic acuity score (SA) was defined in this study as the standard deviation of 15 rangings made with a stereoptometer on a target at 3020 millimeters. The wearing of some contact lenses (rather than spectacles) did alter the stereoptic acuities of some wearers. The differential performances with the different lenses were dependent, however, upon the differences among subjects. Thus, whereas a given subject might have obtained a lower stereoptic acuity score with a given type of lens, another subject might have obtained a higher score with the same type of lens. Consequently, whereas one given type of lens might have been better than spectacles for a given subject, the same type of lens might have been worse than spectacles for another subject.

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CHANGES IN VISUAL DEPTH PERCEPTION WITH THE WEARING OF CONTACT LENSES

I. INTRODUCTION

One of the psychophysiological criteria which might be used in judging the adequacy of contact lenses as alternates for spectacles is that which relates to the performance of the wearer in tasks of visual depth perception. A listing of other factors which might be used to evaluate contact lenses would include such items as the material structure and refractive status of the lenses, the visual acuity and color vision performances of the wearer, the development of photophobia, etc., and other factors specific to the situational demands of the evaluating agency. Such a comprehensive evaluation for the military utilization of contact lenses has been reported by McGraw and Enoch (7). The present report, however, is concerned only with visual depth perception as defined by a single specific task--stereo-ranging. This selection was made because performance with a binocular stereoscopic range finder appeared to be the most acute of the military tasks demanding the use of visual depth perception.

A series of stereo-rangings on a single target at a given distance may be summarized by two statistical measures, the arithmetic mean and the standard deviation. Since the mean range is a measure of the central tendency (or average) of the rangings, it may be considered a spatial localization score (SL). Insofar as it differs from the "true" target distance, the SL may serve as a measure of the constant error in the rangings. The standard deviation, on the other hand, is a measure of the variability of the rangings, and may be considered a stereoptic acuity score (SA).* Thus, by summarizing the ranging data into these two measures, the errors in ranging are divided into their constant and variable components. This division should prove helpful both in the discovery of any real differences which may exist among the lenses and in an evaluation of the lenses in view of these differences.

The hypotheses that changes in spatial localization and changes in stereoptic acuity might take place when some contact lenses are worn would seem consistent with the fact that certain changes do take place in the cornea when some contact lenses are worn. A preliminary test of these hypotheses in a pilot study (2) resulted in support of the

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*Unless otherwise stated, the term "stereoptic acuity" will be used to mean specifically "binocular stereoptic acuity".

hypothesis concerning spatial localization although no conclusion was reached concerning the tenability of the stereoptic acuity hypothesis. The test of these hypotheses remains, then, the primary purpose of the present study. Simply stated, the questions are: Does the wearing of contact lenses (rather than spectacles) alter the stereoptic acuity of the wearer? Does the wearing of contact lenses (rather than spectacles) result in a change in the wearer's spatial localizations?

The secondary purpose of this study is to evaluate the contact lenses used with respect to the depth performances obtained when they were worn and when spectacles were worn. In order to evaluate, however, one must identify desirable and undesirable characteristics. This is not difficult with stereoptic acuity. Of two SAs, the better is the smaller score (the less variable rangings). The establishment of a criterion for spatial localization is more complex, however. A constant difference in SL between any given type of contact lens and spectacles would not necessarily yield different ranging errors in the operation of a binocular stereoscopic range finder, for the instrument carries the provision for correction of constant errors (the "ICS" setting). It would mean, however, that separate "ICS" settings should be determined for the different lenses. On the other hand, were the difference not a constant one, but rather one which varied with the length of time the lenses were worn, for example, then the lenses with the lesser variation in SLs would be preferred.

The following, then, form the criteria for the evaluation of the contact lenses used in this study:

If differences in stereoptic acuity exist when spectacles and the different contact lenses are worn, the lenses will be ranked in preferability inversely with the absolute magnitudes of the mean stereoptic acuity scores obtained.

If differences in spatial localization exist when spectacles and different contact lenses are worn, and if these differences are not constant but variable from one series of rangings to another, the lenses will be ranked in preferability inversely with the absolute magnitudes of the variances of the spatial localization scores obtained.

II. EXPERIMENTAL

The present study was designed with the cooperation of personnel of a contact lens evaluation project.* During each of their five testing

*Environmental Physiology, AMRL Project No. 6-64-12-028, Subtask, Contact Lens Studies; reported by McGraw and Enoch(7).

cycles, all ten subjects of the contact lens project were made available for the study reported here. Each subject had been previously refracted and fitted with spectacles and four types of contact lenses. The ages and refractive information concerning these subjects are reprinted from McGraw and Enoch (7) in Table 1.

TABLE I

AGES AND REFRACTIVE DATA OF SUBJECTS

SUBJECT	AGE *	VISUAL ACUITY						CYCLOPLEGIC	ACCEPTANCE
		UNCORRECTED			CORRECTED				
		O D	O S	O U	O D	O S	O U	O D	O S
R G A	22	20/200+	20/200	20/200+	20/15	20/15	20/15	- 2.75 • - 0.75 X 120	- 2.75 • - 0.75 X 68
J L A	21	20/200	20/300	20/200	20/15	20/15	20/15	- 2.50 • - 0.25 X 90	- 2.50 • - 0.50 X 90
C J D	22	20/60-	20/60-	20/60+	20/15	20/15	20/15	- 0.75 • - 0.75 X 110	- 0.50 • - 0.75 X 25
J L E	22	20/100	20/20	20/20	20/15	20/15	20/15	+ 4.25 • - 2.50 X 3	+ 3.00 • - 1.00 X 5
D J F	20	20/300	20/200	20/200	20/15	20/15	20/15	- 3.25	- 2.75 • - 0.50 X 180
J K H	26	20/15	20/80	20/15	20/15	20/60	20/15	+ 3.75 • - 0.25 X 90	+ 3.75 • - 0.50 X 90
D R M	22	20/200	20/200	20/200	20/15	20/15	20/15	- 3.75 • - 1.25 X 175	- 2.75 • - 1.00 X 5
L F P	22	20/400	10/400	20/400	20/20	20/20	20/15	- 4.00 • - 4.00 X 3	- 4.00 • - 4.00 X 180
E J S	22	20/400	10/400	20/400	20/20+	20/20	20/20+	- 3.50	- 5.25 • - 0.25 X 180
J LW	20	20/200	20/200	20/200	20/20	20/20	20/20	+ 10.00 • - 2.50 X 175	+ 10.00 • - 1.75 X 175

* AS OF 15 APRIL 1951

A. Apparatus and Methods

A pilot model stereoptometer, partly modified as recommended in the pilot study (2), was the ranging apparatus used. Because this instrument is reported elsewhere (3, 4), the description below is limited to the minimum necessary for understanding the experimental procedure.

Basically, the stereoptometer is a unit base, unit power, binocular stereoscopic range finder. It consists of two U. S. A. F. reflex gun sights, each modified by the addition of an eye cup so placed, and with sufficient aperture, to require no adjustment for the differing interpupillary distances of the test subjects used. One sight is mounted rigidly to a base. The other is mounted on a bearing which allows rotation about the eye cup in a horizontal arc. The tangent of the angle of rotation is found by use of a thousandth-inch dial gauge measuring from a point calibrated as being 9. 060 inches from the center of rotation. The reticle pattern used provided a yellow-orange circular image which subtended 15 minutes of visual angle at the plane of the eye cups. Both a head rest and a chin cup were provided to stabilize the subject's head when positioned to range. The ambient illumination at the position of the eye cups, as measured in a parasagittal plane with a Macbeth illuminometer, varied unsystematically between 95 and 111 foot-candles.

The target was a white cardboard rectangle 9 inches high and 3 inches wide, with an inch square cut out of the upper-right corner. The brightness of the target, as measured with a Macbeth illuminometer, varied unsystematically between 13 and 14 foot-lamberts throughout the course of the study. The target was so supported by a metal rod attached to a tripod that its top was held at a constant 1.27 meters above the floor level (the eye cups of the stereoptometer were 1.33 meters above the floor). The target was placed in a frontal plane 3.020 meters from the vertical plane of the eye cups. The general level of ambient illumination about the target was 35 to 40 foot-candles. Several familiar objects* were placed to the left-rear and right-rear of the target within the subject's field of view to structure the target field and thus better insure subjective stability of the field. Background for the entire target field was provided by black flocked screens of low reflectance.

The ranging task was one which required stereoptic abilities for completion. With his head positioned in the chin cup and head rest, the subject viewed the target binocularly through the reflex sights. The two indefinitely projected reticle images were fused into a single reticle image projected to a determinable distance. By turning a knob on the instrument, the subject was able to rotate the movable sight, thus adjusting the right-left displacement of the right reticle beam. This adjustment resulted in phenomenal movement of the single fused reticle image in depth.** The "on-target" condition occurred with the

*These objects were: to the left-rear of the target, a chair with a book and a cough-drop package on the seat; to the right-rear of the target, a stool with a package of cigarettes on the seat.

**Actually, with this asymmetrical vergence of the reticle beams, the fused reticle image appeared to move obliquely from far-right to near-left, and vice versa. At the time this study was begun, no instrument which provided symmetrical vergence of both reticle beams was available. The recommendation of the pilot study (2) that such symmetrical vergence be provided was, thus, necessarily disregarded. A stereoptometer which does provide symmetrical vergence of both reticle beams, as well as asymmetrical vergence of either the right or left beam, has been recently reported by Harker (6).

phenomenal depth alignment of reticle image and target. The subject was instructed to "point" the stereoptometer, by rotation about its base, so that when the "on-target" condition was reported, the reticle image would appear within the inch square cut out of the target.

A three-factor analysis of variance design, with lenses (Ls), times of measurement (T), and subjects (Sub), as major effects, was used. The spectacles and contact lenses worn by the subjects have been described by McGraw and Enoch (7). The spectacles (S) were standard Army issue. The contact lenses were:

1. Obrig fluid (O)--plastic, fluid, corneal-scleral lenses.
2. Obrig Lacrilens (L)--plastic, ventilated, fluidless, corneal-scleral lenses.
3. Dallos (D)--glass, ventilated, fluidless, corneal-scleral lenses.
4. Tuohy (Tu)--plastic, fluidless, corneal lenses.

The design called for each subject to range six times between 0800 and 1700 hours at 1 1/2 hour intervals during each of the five days of measurement. During each of the six times of measurement, each subject completed a series of 15 rangings on the target by the method of adjustment as described above. When contact lenses were worn, the lenses were inserted 10 minutes before the first series of rangings. Some of the subjects, while wearing some of the lenses, were not able to complete a full day's rangings. This will be discussed further in the Results Section. The specific lenses worn by the subjects on the dates of measurement during each of the five testing cycles are given in Table 2. These assignments were made by personnel of the contact lens project.

TABLE 2

LENSES WORN BY SUBJECTS DURING DIFFERENT DAYS OF MEASUREMENT

Subjects	Date of Measurement (1952)				
	(Cycle I) 29 Feb	(Cycle II) 2 May	(Cycle III) 20 Jun	(Cycle IV) 8 Jul	(Cycle V) 6 Aug
DJF	L	Tu**	S	O	D
JLE	S	O	D	L	Tu
DRM	O	D*	L	S	Tu
RGA	Tu	S	O	D	L
LFP	L	D	Tu	S	O
JLA	Tu	S	O	D	L
CJD	O	D*	L	Tu	S
JLW	S	O	L	D	Tu
EJS	L	Tu	S	O	D
JKH	D#	--	--	--	--

S--Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluidless lenses; Tu--Tuohy corneal lenses.

* 21 April 1952
** 7 May 1952
\# JKH did not evidence fused binocular vision, and so was excluded from the study.

The data recorded were functions of the tangent of the angle of rotation of the right reticle beam with respect to the left. These tangential data were transmuted into linear ranges through the use of an interpupillary base estimate (IBE) calculated for each subject from the mean of his six experimental series of rangings made while wearing spectacles. In calculating these IBEs, the assumption was made that the mean of the rangings with spectacles would be a subject's best estimate of a "true" range, i. e., a ranging with no constant error. Thus, each IBE (in millimeters) was calculated by "placing" the mean ranging with spectacles "on-target" according to the equation:

$$\text{IBE} = (3020)\ (\text{Mean Gauge Reading})/(9060) = k/9060.$$

Once this had been computed for each subject, the transmutation of all the tangential data was accomplished by substitution in the equation:

$$\text{Range} = (9060)(\text{IBE})/(\text{Gauge Reading}) = k/\text{Gauge Reading}.$$

Since the gauge readings were expressed in thousandths of an inch, the ranges obtained in this manner were expressed in the same units as the IBEs (millimeters). All further calculations were based on these transmuted linear-ranging data, not on the original tangential data.

B. Results

As was indicated in Table 2, JKH failed to evidence fused binocular vision and so was excluded from the study. This action reduced the number of subjects from ten to nine. During the course of the experiment, JLW was able to complete the six series of rangings with spectacles and Dallos lenses only. Because his data for the three other contact lenses were incomplete, all data obtained from this subject were excluded from the following analyses. The summary tables for these excluded data are appended to this report as Tables 15 and 16. Also excluded from the analyses were all the data obtained with the Tuohy lenses, because only one subject (JLA) was able to wear these lenses without extreme discomfort for the 7 3/4 hours duration necessary to complete the six series of rangings. The summary tables of these data for the Tuohy lenses are appended as Tables 17 and 18. The analyses presented below, then, are based on data for four lenses (S, O, L, and D), six times of measurement, and eight subjects.

1. Stereoptic Acuity.

Table 3 presents the stereoptic acuity scores of the eight subjects for each of the four lenses at each of the six times of measurement. Table 4 presents the summary of an analysis of variance of these data. This analysis indicates that there was a statistically significant minor effect (the interaction of lenses and subjects). Two of

TABLE 3
STEREOPTIC ACUITY SCORES* OF 8 SUBJECTS FOR 4 TYPES OF LENSES AT 6 TIMES OF MEASUREMENT

Subjects	Lenses	Times of Measurement (Minutes Since Insertion of Lenses)						Total
		1 (10)	2 (100)	3 (190)	4 (280)	5 (370)	6 (460)	
DJF	S	24.16	18.87	9.15	28.55	19.55	19.57	117.85
	O	15.54	22.28	22.49	28.12	24.98	45.13	158.54
	L	18.07	16.27	15.76	28.29	20.36	14.49	113.24
	D	24.34	15.93	9.91	13.64	16.11	18.80	98.73
	Total	82.11	71.35	57.31	98.60	81.00	97.99	488.36
JLE	S	53.03	45.72	28.14	26.33	25.18	44.13	222.53
	O	46.04	85.52	126.42	51.95	77.47	53.57	440.97
	L	36.59	59.82	96.36	70.72	46.24	62.28	372.01
	D	29.51	18.13	18.93	83.43	27.67	45.20	222.87
	Total	165.17	209.19	269.85	232.43	176.56	205.18	1258.38
DRM	S	16.88	27.56	24.80	28.23	27.78	27.96	153.21
	O	61.73	56.85	17.29	36.93	30.34	81.29	284.43
	L	14.18	12.99	10.37	14.90	18.61	13.47	84.52
	D	25.66	17.86	15.75	20.66	19.15	20.12	119.20
	Total	118.45	115.26	68.21	100.72	95.88	142.84	641.36
RGA	S	52.63	25.21	38.62	24.60	21.97	37.30	200.33
	O	32.46	28.97	28.96	25.30	40.22	26.16	182.07
	L	28.22	31.29	52.21	32.29	24.46	26.32	194.79
	D	24.11	66.20	42.97	28.10	34.38	40.85	236.61
	Total	137.42	151.67	162.76	110.29	121.03	130.63	813.80
LFP	S	29.47	40.98	36.45	32.40	39.89	29.56	208.75
	O	39.74	22.93	43.97	36.55	33.10	77.52	253.81
	L	30.70	41.09	32.21	70.06	50.71	39.89	264.66
	D	28.92	35.40	47.78	38.74	48.29	30.82	229.95
	Total	128.83	140.40	160.41	177.75	171.99	177.79	957.17
JLA	S	28.62	19.85	24.44	30.96	34.60	23.71	162.18
	O	36.45	35.96	18.36	13.26	20.01	25.72	149.76
	L	14.78	27.87	12.46	19.31	13.82	16.89	105.13
	D	18.28	14.66	18.92	20.30	17.01	19.62	106.79
	Total	96.13	98.34	74.18	83.83	85.44	85.94	523.86
CJD	S	17.25	24.92	21.58	7.36	20.51	25.48	117.10
	O	45.51	48.94	32.91	24.02	47.66	50.00	249.04
	L	35.73	21.94	31.40	22.57	87.19	62.14	260.97
	D	12.11	18.52	14.47	17.92	15.94	16.34	95.30
	Total	110.60	114.32	100.36	71.87	171.30	153.96	722.41
EJS	S	11.87	17.81	21.27	14.40	16.99	16.40	98.74
	O	24.11	14.32	16.70	20.94	15.91	11.21	103.19
	L	38.68	46.85	43.39	32.90	22.17	17.15	201.14
	D	18.47	17.40	23.96	16.70	18.78	31.75	127.15
	Total	93.13	96.38	105.32	85.03	73.85	76.51	530.22
Total	S	233.91	218.92	204.45	192.83	206.47	224.11	1280.69
	O	301.58	315.77	307.10	237.07	289.69	370.60	1821.81
	L	216.95	258.12	294.16	291.04	283.56	252.63	1596.46
	D	179.40	204.10	192.69	239.58	197.33	223.50	1236.60
	Total	931.84	996.91	998.40	960.52	977.05	1070.84	5935.56

*Standard deviations of 15 rangings, in millimeters. Target distance was 3020 millimeters.
S--Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluid lenses.

TABLE 4

ANALYSIS OF VARIANCE OF DATA OF TABLE 3

Source of Variation	Sum of Squares	df	Variance Estimate	Error Term	F	F necessary for p=.05* or p=.01#
Lenses (Ls)	4777.18	3	1592.39	(LsxSub)	( )	( )
Times (T)	345.92	5	69.18	LsxTxSub	0.39	2.30*
Subjects (Sub)	20224.29	7	2889.18	(LsxSub)	( )	( )
Ls x T	1799.40	15	119.96	LsxTxSub	0.68	1.77*
Ls x Sub	11273.39	21	536.83	LsxTxSub	3.05	2.04#
T x Sub	5499.27	35	157.12	LsxTxSub	0.89	1.54*
Ls x T x Sub	18492.64	105	176.12	---	---	---
Total	62412.09	191	---	---	---	---

F values in this and following tables are from Edwards (5, pp. 410-413).

* The 5 per cent point for the distribution of F with the given degrees of freedom (df).

The 1 per cent point for the distribution of F with the given df.

( ) No F-ratio computed because of significant but non-homogeneous (LsxSub).

the major effects (the differences among lenses, and the differences among subjects) could not be tested in this analysis because the "lens by subject" interaction was both statistically significant and non-homogeneous. A Bartlett's test for homogeneity of variance, computed for the variances of the 32 "lens by subject" rows of Table 3, resulted in a corrected Chi-square of 139.59. This is associated with a probability of less than .0001. Because of this rejection of the hypothesis of homogeneous variances for the specific rows tested, no single over-all test could be made either for the differences among lenses, or for the differences among subjects. Instead, the differences among lenses could be tested only by levels of subjects, and the differences among subjects could be tested only by levels of lenses.

Table 5 presents, for each of the four lenses separately, the summary of an analysis of variance of the SAs obtained with these lenses. These results indicate that the differences among subjects were statistically significant with each of the lenses. They indicate also that the differences among the times of measurement (the lengths of time the lenses were worn) were not statistically significant with any of the lenses.

TABLE 5

ANALYSIS OF VARIANCE OF DATA OF TABLE 3
BY LEVELS OF LENSES

Lenses	Source of Variation	Sum of Squares	df	Variance Estimate	F * #
Spectacles	Subjects (Sub)	2555.61	7	365.09	6.01#
	Times (T)	139.63	5	27.93	0.46
	Sub x T	2125.40	35	60.73	---
	Total	4820.64	47	---	---
Obrig Fluid	Sub	13047.02	7	1863.86	6.73#
	T	1159.15	5	231.83	0.84
	Sub x T	9692.51	35	276.93	---
	Total	23898.68	47	---	---
Obrig Lacrilens	Sub	11229.30	7	1604.19	7.42#
	T	546.88	5	109.38	0.51
	Sub x T	7571.24	35	216.32	---
	Total	19347.42	47	---	---
Dallos	Sub	4665.74	7	666.53	5.07#
	T	299.66	5	59.93	0.46
	Sub x T	4602.76	35	131.51	---
	Total	9568.16	47	---	---

* For the given df, the F-ratios necessary for $p = .05$ are; 2.29 for Sub, and 2.49 for T.

\# For $p = .01$, the values are:
3.20 for Sub, and
3.60 for T.

Table 6 presents, for each of the eight subjects separately, the summary of an analysis of variance of the SAs of each subject. These analyses indicate that the differences among lenses were statistically significant in the cases of four subjects (JLE, DRM, CJD, and EJS), and so closely approached it with one other subject (JLA) that his data also were considered statistically significant. In the case of no subject were the differences among the times of measurement statistically significant.

TABLE 6

ANALYSIS OF VARIANCE OF DATA OF TABLE 3
BY LEVELS OF SUBJECTS

Subject	Source of Variation	Sum of Squares	df	Variance Estimate	F *#
DJF	Lenses (Ls)	328.43	3	109.48	2.50
	Times (T)	313.27	5	62.65	1.43
	Ls x T	656.30	15	43.75	---
	Total	1298.00	23	---	---
JLE	Ls	6026.09	3	2008.70	3.47*
	T	1809.14	5	361.83	0.62
	Ls x T	8687.27	15	579.15	---
	Total	16522.50	23	---	---
DRM	Ls	3815.06	3	1271.69	8.86#
	T	787.88	5	157.58	1.10
	Ls x T	2152.58	15	143.51	---
	Total	6755.52	23	---	---
RGA	Ls	273.57	3	91.19	0.68
	T	469.20	5	93.84	0.70
	Ls x T	1997.87	15	133.19	---
	Total	2740.64	23	---	---
LFP	Ls	312.40	3	104.13	0.57
	T	532.47	5	106.49	0.58
	Ls x T	2746.20	15	183.08	---
	Total	3591.07	23	---	---
JLA	Ls	429.92	3	143.31	3.13*
	T	97.33	5	19.47	0.43
	Ls x T	686.91	15	45.79	---
	Total	1214.16	23	---	---
CJD	Ls	3741.95	3	1247.32	7.41#
	T	1651.71	5	330.34	1.96
	Ls x T	2525.68	15	168.38	---
	Total	7919.34	23	---	---
EJS	Ls	1123.15	3	374.38	6.69#
	T	184.19	5	36.84	0.66
	Ls x T	839.22	15	55.95	---
	Total	2146.56	23	---	---

*For the given df, the F-ratios necessary for $p = .05$ are: 3.29 for Ls, and 2.90 for T.

#For $p = .01$, the values are: 5.42 for Ls, and 4.56 for T

Table 7 presents the significances of differences in mean SAs between spectacles and each of the contact lenses for the five subjects with whom the preceding analyses showed the differences among lenses as probably significant. Assuming that the direction of the differences is constant for any given subject with any given lenses (e. g., that JLE would again obtain a greater mean SA with O than with S), the one-tailed test of significance would seem appropriate. Using such a test, it is seen that the mean SA with O was significantly greater than that with S for three subjects (JLE, DRM, and CJD). The mean SA with L was also significantly greater than that with S for three subjects (JLE, CJD, and EJS), but it was significantly lesser for the other two subjects (DRM and JLA). The mean SA with D was significantly greater than that with S for one subject (EJS), but significantly lesser with another subject (JLA).

TABLE 7

SIGNIFICANCES OF DIFFERENCES IN MEAN STEREOPTIC ACUITY SCORES BETWEEN SPECTACLES AND CONTACT LENSES FOR 5 SUBJECTS@

Subjects	Lenses	Mean (mm)	Differences Tested	t&	r¢
JLE	S	37.09			
	O	73.50	S - O	2.41*	-.422
	L	62.00	S - L	2.12*	-.512
	D	37.14	S - D	0.00	-.305
DRM	S	25.54			
	O	47.40	S - O	2.19*	-.129
	L	14.09	S - L	5.89#	+.177
	D	19.87	S - D	1.95	-.678
JLA	S	27.03			
	O	24.96	S - O	0.39	-.503
	L	17.52	S - L	2.40*	-.560
	D	17.80	S - D	4.30#	+.257
CJD	S	19.52			
	O	41.51	S - O	8.15#	+.799
	L	43.50	S - L	2.39*	+.329
	D	15.88	S - D	1.25	-.027
EJS	S	16.46			
	O	17.20	S - O	0.26	-.624
	L	33.52	S - L	3.60#	+.202
	D	21.19	S - D	2.04*	+.304

@Data of Table 3. The formula used in computing these and following t-tests was a computational form of the usual difference formula, $t^2 = M_d^2/s_{M_d}^2$. Using L-notation, where $L_{xy} = N\Sigma XY - \Sigma X \Sigma Y$, this formula can be written as: $t^2 = (\Sigma X - \Sigma Y)^2 (N - 1)/L_{xx} + L_{yy} - 2L_{xy}$.

S+-Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluidless lenses.

&t-values in this and following tables are from Edwards (5, p. 407)

*Difference statistically significant beyond the 5 per cent point (df = 5; t = 2.015).

#Difference statistically significant beyond the 1 per cent point (df = 5; t = 3.365).

¢For the 4 df available, the r associated with the 5 per cent level of significance is .811. This value, and r-values in following tables, are from Edwards (5, p. 408).

These findings concerning the stereoptic acuity scores may be summarized as follows:

a. There were no statistically significant differences attributable to the times of measurement (the lengths of time the lenses were worn).

b. There were statistically significant differences attributable to the interaction of lenses and subjects, but the variances of these (Ls x Sub) scores were found to be non-homogeneous. Therefore, the statistical significance of the differences among subjects was obtained for each of the lenses, and the statistical significance of the differences among lenses was obtained for each of the subjects.

c. The differences among subjects were statistically significant with each of the lenses.

d. The differences among lenses were statistically significant for five of the eight subjects. Of these five subjects: (a) three obtained greater mean stereoptic acuity scores with the Obrig fluid lenses than with spectacles, whereas the differences were not statistically significant for the other two subjects; (b) three subjects obtained greater mean scores with the Obrig Lacrilens than with spectacles, although two subjects obtained lesser mean scores with these lenses; and (c) one subject obtained a greater mean score with the Dallos lenses than he did with spectacles, but another subject obtained a lesser mean score with these lenses than with spectacles, whereas the differences were not statistically significant for the other three subjects.

2. Spatial Localization.

Table 8 presents the spatial localization scores of the eight subjects for each of the four lenses at each of the six times of measurement. Table 9 presents the summary of an analysis of variance of these data. This analysis indicates that there was a statistically significant major effect (the differences among the times of measurement), and a statistically significant minor effect (the interaction of lenses and subjects). Two major effects (the differences among lenses, and the differences among subjects) could not be tested in this analysis because the "lens by subject" interaction was both statistically significant and non-homogeneous. A Bartlett's test for homogeneity of variance, computed for the variances of the 32 "lens by subject" rows of Table 8, resulted in a corrected Chi-square of

55.96. This is associated with a probability of less than .003. Because of this rejection of the hypothesis of homogeneous variances for the specific rows tested, no single over-all test could be made for the differences among lenses (nor for the differences among subjects). Instead, the differences among lenses could be tested only by levels of subjects, and the differences among subjects could be tested only by levels of lenses.

TABLE 8

SPATIAL LOCALIZATION SCORES* OF 8 SUBJECTS FOR 4 TYPES OF LENSES AT 6 TIMES OF MEASUREMENT

Subjects	Lenses	Times of Measurement (Minutes since insertion of lenses)						Total
		1 (10)	2 (100)	3 (190)	4 (280)	5 (370)	6 (460)	
DJF	S	3041	3045	3025	2966	3009	3037	18123
	O	3074	3031	3016	3061	3054	3048	18284
	L	2682	2677	2608	2771	2798	2712	16248
	D	3015	2973	2979	3017	2949	2954	17887
	Total	11812	11726	11628	11815	11810	11751	70542
JLE	S	3051	3008	3039	2985	3010	3030	18123
	O	3028	2994	3060	3007	3090	3015	18194
	L	3041	3160	3091	3129	3056	3123	18600
	D	3070	3026	3040	3062	3059	3049	18306
	Total	12190	12188	12230	12183	12215	12217	73223
DRM	S	3010	3049	2979	3029	3026	3028	18121
	O	2950	2958	3061	3088	3060	3009	18126
	L	3002	3026	3042	3020	2995	3040	18125
	D	2974	3034	3057	3059	3047	3071	18242
	Total	11936	12067	12139	12196	12128	12148	72614
RGA	S	2967	3029	3006	3064	3039	3018	18123
	O	2949	2956	2979	2966	2980	2958	17788
	L	2906	3027	2921	2956	2974	3021	17805
	D	2953	2924	3006	2975	2987	2970	17815
	Total	11775	11936	11912	11961	11980	11967	71531
LFP	S	3034	3005	3018	3026	2988	3054	18125
	O	2976	2975	2901	3012	2937	2921	17722
	L	3033	3027	2998	3081	3012	3062	18213
	D	3061	3018	2986	2984	2992	3058	18099
	Total	12104	12025	11903	12103	11929	12095	72159
JLA	S	3029	3023	3017	3001	3013	3040	18123
	O	3057	3096	3086	3070	3086	3045	18440
	L	3042	3003	2996	2987	2998	3045	18071
	D	3043	3056	3017	3085	3085	3100	18386
	Total	12171	12178	12116	12143	12182	12230	73020
CJD	S	3009	3056	3006	2993	3041	3018	18123
	O	2977	2995	3022	3050	3003	3002	18049
	L	3037	2923	2938	3022	2963	2894	17777
	D	3055	3048	3028	3079	3062	3032	18304
	Total	12078	12022	11994	12144	12069	11946	72253
DJF	S	3011	3024	3001	3024	3034	3029	18123
	O	2995	2994	3002	3046	3001	3055	18093
	L	2968	3010	3013	3028	3011	3010	18040
	D	2913	3007	2890	2938	2896	3000	17644
	Total	11887	12035	11906	12036	11942	12094	71900
Total	S	24152	24239	24091	24088	24160	24254	144984
	O	24006	23999	24127	24300	24211	24053	144696
	L	23711	23853	23607	23994	23807	23907	142879
	D	24084	24086	24003	24199	24077	24234	144683
	Total	95953	96177	95828	96581	96255	96448	577242

*Arithmetic means of 15 rangings, in millimeters. Target distance was 3020 millimeters.
S--Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluidless lenses.

TABLE 9

ANALYSIS OF VARIANCE OF DATA OF TABLE 8

Source of Variation	Sum of Squares	df	Variance Estimate	Error Term	F	F necessary for p = .05* or p = .01#
Lenses (Ls)	58128	3	19376	(LsxSub)	( )	( )
Times (T)	12791	5	2558	LsxTxSub	2.34	2.30*
Subjects (Sub)	215222	7	30746	(LsxSub)	( )	( )
Ls x T	16062	15	1071	LsxTxSub	0.98	1.77*
Ls x Sub	509303	21	24253	LsxTxSub	22.19	2.04#
T x Sub	38974	35	1114	LsxTxSub	1.02	1.54*
Ls x T x Sub	114732	105	1093	---	---	---
Total	965212	191	---	---	---	---

*The 5 per cent point for the distribution of F with the given df.
#The 1 per cent point for the distribution of F with the given df.
( ) No F-ratio computed because of significant but non-homogeneous (LsxSub).

Table 10 presents, for each of the four lenses separately, the summary of an analysis of variance of the SLs obtained with these lenses. These results indicate that the differences among subjects were statistically significant with each of the lenses except spectacles. The fact that the differences among subjects were not statistically significant with spectacles is, in reality, an artifact resulting from the method of transmuting the data by using the interpupillary base estimate. The only differences among subjects evident from the data for spectacles in the "Total" column of Table 8 are differences due to errors of rounding. The interesting finding in Table 10, however, is the indication that even though the subjects were equated in SLs when wearing spectacles, they did not remain equated in SLs when wearing the other lenses. Evidently, an IBE would have to be com-

TABLE 10

ANALYSIS OF VARIANCE OF DATA OF TABLE 8 BY LEVELS OF LENSES

Lenses	Source of Variation	Sum of Squares	df	Variance Estimate	F *#
Spectacles	Subjects (Sub)	1	7	0.14	---
	Times (T)	3124	5	625	1.12
	Sub x T	19449	35	556	---
	Total	22574	47	---	---
Obrig Fluid	Sub	66749	7	9536	9.67#
	T	9095	5	1819	1.84
	Sub x T	34496	35	986	---
	Total	110340	47	---	---
Obrig Lacrilens	Sub	571302	7	81615	45.70#
	T	12009	5	2402	1.34
	Sub x T	62498	35	1786	---
	Total	645809	47	---	---
Dallos	Sub	86472	7	12353	11.60#
	T	4625	5	925	0.87
	Sub x T	37263	35	1065	---
	Total	128360	47	---	---

*For the given df, the F-ratios necessary for p = .05 are: 2.29 for Sub, and 2.49 for T.
#For p = .01, the values are: 3.20 for Sub, and 3.60 for T.

puted for each lens-subject combination, if subjects were to be equated in SLs with each of the lenses. This is tantamount to saying that an "ICS" setting would have to be obtained for each lens-operator combination if operators of binocular stereoscopic range finders were to be equated in mean rangings with each of the different types of lenses used in this study. The results presented in Table 10 indicate also that the differences among the times of measurement (the lengths of time the lenses were worn) were not statistically significant with any of the lenses.

Table 11 presents, for each of the eight subjects separately, the summary of an analysis of variance of the SLs of each subject. These analyses indicate that the differences among lenses were statistically significant in the cases of seven subjects (all except DRM). In the case of no subject were the differences among the times of measurement statistically significant.

TABLE 11

ANALYSIS OF VARIANCE OF DATA OF TABLE 8 BY LEVELS OF SUBJECTS

Subject	Source of Variation	Sum of Squares	df	Variance Estimate	F * #
DJF	Lenses (Ls)	441103	3	147034	79.09#
	Times (T)	6709	5	1342	0.72
	Ls x T	27892	15	1859	---
	Total	475704	23	---	---
JLE	Ls	22078	3	7359	5.33*
	T	465	5	93	0.07
	Ls x T	20710	15	1381	---
	Total	43253	23	---	---
DRM	Ls	1743	3	581	0.51
	T	10444	5	2089	1.84
	Ls x T	17039	15	1136	---
	Total	29226	23	---	---
RGA	Ls	12889	3	4296	4.15*
	T	7204	5	1441	1.39
	Ls x T	15521	15	1035	---
	Total	35614	23	---	---
LFP	Ls	23626	3	7875	9.94#
	T	10328	5	2066	2.61
	Ls x T	11886	15	792	---
	Total	45840	23	---	---
JLA	Ls	17111	3	5704	9.51#
	T	1864	5	373	0.62
	Ls x T	8997	15	600	---
	Total	27972	23	---	---
CJD	Ls	23945	3	7982	6.80#
	T	6087	5	1217	1.04
	Ls x T	17612	15	1174	---
	Total	47644	23	---	---
EJS	Ls	24936	3	8312	11.20#
	T	8665	5	1733	2.34
	Ls x T	11136	15	742	---
	Total	44737	23	---	---

*For the given df, the F-ratios necessary for $p = .05$ are: 3.29 for Ls, and 2.90 for T.

#For $p = .01$, the values are: 5.42 for Ls, and 4.56 for T.

Table 12 presents the significances of differences in mean SLs between spectacles and each of the contact lenses for the seven subjects with whom the preceding analyses showed differences among lenses as statistically significant. Assuming that the direction of the differences is constant for any given subject with any given lenses (e.g., that DJF would always range farther with O than with S), the one-tailed test of significance would seem appropriate. Using such a test, it is seen that the mean SL with O was significantly greater (the target was ranged as farther) than with S for one subject (JLA), significantly lesser (the target was ranged as nearer) for two subjects (RGA and LFP), and not significantly different statistically for the remaining four subjects. The mean SL with L was significantly greater than with S for one subject (JLE), significantly lesser for two subjects (DJF and RGA), and not significantly different statistically for the remaining four subjects. The mean SL with D was significantly greater than with S for three subjects (JLE, JLA, and CJD), significantly lesser for two subjects (RGA and EJS), and not significantly different statistically for the remaining two subjects.

TABLE 12

SIGNIFICANCES OF DIFFERENCES IN MEAN SPATIAL LOCALIZATION SCORES BETWEEN SPECTACLES AND CONTACT LENSES FOR 7 SUBJECTS@

Subject	Lenses	Mean (mm)	Difference Tested	t*#	r¢
DJF	S	3020			
	O	3047	S - O	1.62	-.259
	L	2708	S - L	8.51#	-.600
	D	2981	S - D	1.98	-.356
JLE	S	3020			
	O	3032	S - O	0.75	+.228
	L	3100	S - L	3.12*	-.557
	D	3051	S - D	2.71*	+.101
RGA	S	3020			
	O	2965	S - O	4.63#	+.439
	L	2968	S - L	2.90*	+.482
	D	2969	S - D	3.08*	+.114
LFP	S	3021			
	O	2954	S - O	3.45#	-.027
	L	3036	S - L	1.41	+.588
	D	3016	S - D	0.40	+.653
JLA	S	3020			
	O	3073	S - O	4.44#	- 540
	L	3012	S - L	1.50	+.902
	D	3064	S - D	3.21*	+.048
CJD	S	3020			
	O	3008	S - O	0.71	-.523
	L	2963	S - L	1.98	-.504
	D	3051	S - D	2.28*	-.140
EJS	S	3020			
	O	3016	S - O	0.48	+.375
	L	3007	S - L	1.72	+.338
	D	2941	S - D	4.12#	+.436

@Data of Table 8.
S--Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluidless lenses.
*Differences statistically significant beyond the 5 per cent point (df = 5; t = 2.015).
#Difference statistically significant beyond the 1 per cent point (df = 5; t = 3.365).
¢For the 4 df available, the r associated with the 5 per cent level of significance is .811.

Returning to Table 9 and the indicated statistical significance of the differences in SLs among the times of measurement, Figure 1 presents the means of the SLs for the different times of measurement and their least-squares-fitted regression line. The mean SL appears to become greater with time (the target is ranged as farther). The authors know of no immediate explanation for this result.

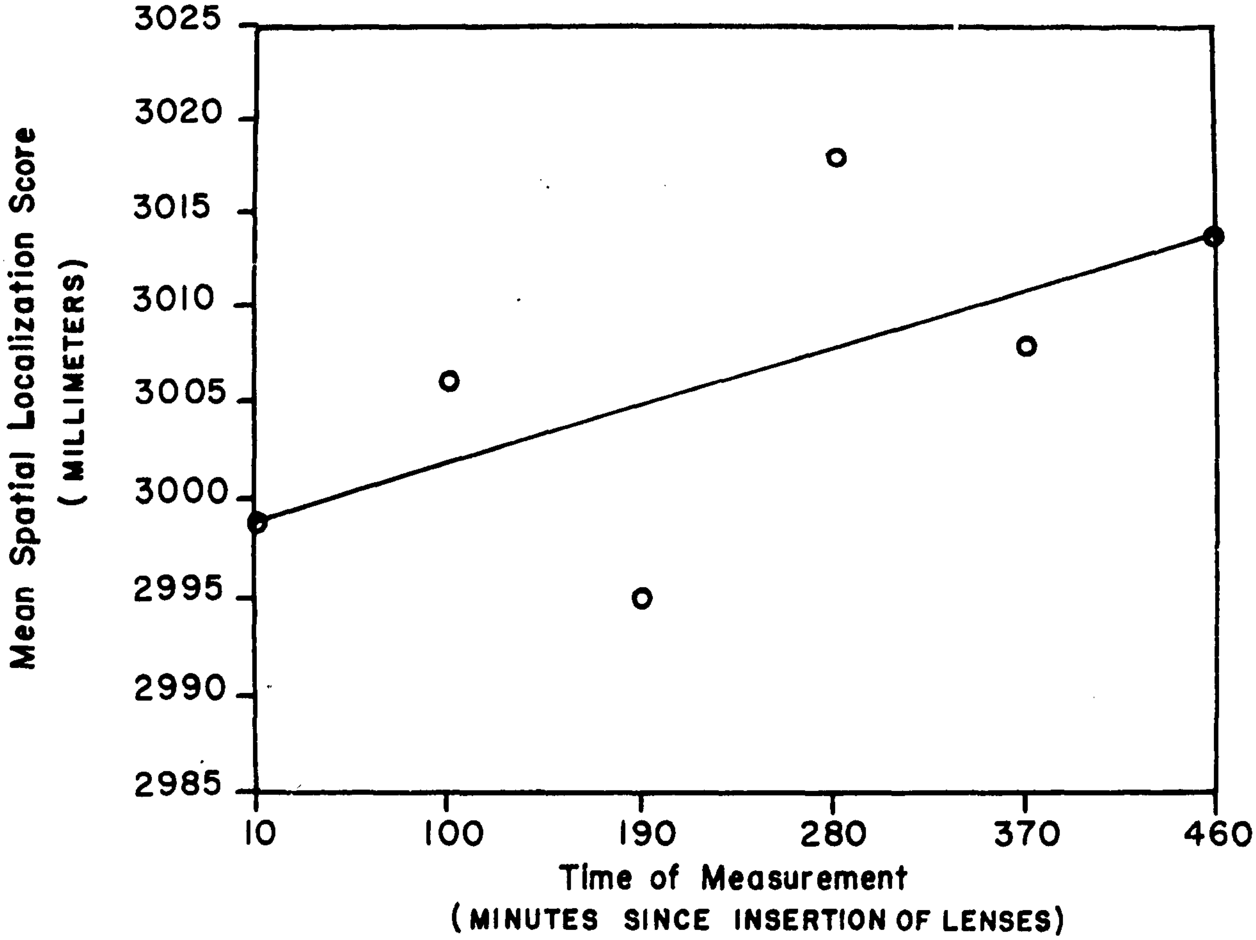

Fig. 1. Means of Spatial Localization Scores for Six Times of Measurement and Their Least-Squares-Fitted Line. (Actual target distance was 3020 millimeters. Data of Table 8.)

The results concerning the spatial localization scores may be summarized as follows:

a. There was an over-all statistically significant difference attributable to the times of measurement (the lengths of time the lenses were worn). This trend was toward obtaining greater spatial localization scores as time increased from the first series of rangings to the sixth (450 minutes after the first).

b. There were statistically significant differences attributable to the interaction of lenses and subjects, but the variances of these (Ls x Sub) scores were found to be non-homogeneous. Therefore, the statistical significance of the differences among subjects was obtained for each of the lenses, and the statistical significance of the differences among lenses was obtained for each of the subjects.

c. The differences among subjects were statistically significant with each of the lenses except spectacles. The occurrence of no differences among subjects with spectacles was explained as an artifact resulting from the method used in originally transmuting the tangential data into linear-ranging data.

d. The differences among lenses were statistically significant for seven of the eight subjects. Of these seven subjects: (a) one obtained a greater mean spatial localization score with the Obrig fluid lenses than with spectacles, two obtained lesser mean scores, and the remaining four subjects obtained non-significant differences between the mean scores with these lenses; (b) one obtained a greater mean score with the Obrig Lacrilens than with spectacles, two obtained lesser mean scores, and the remaining four subjects obtained differences which were not statistically significant; and (c) three subjects obtained greater mean scores with the Dallos fluidless lenses than with spectacles, two obtained lesser mean scores, and the remaining two subjects obtained non-significant differences.

III. DISCUSSION

A. Changes Occurring with Times of Measurement

Tests of the significance of the over-all differences among the mean scores (both SA and SL) for the six times of measurement have resulted in findings of statistically significant differences among the SLs, but non-significant differences among the SAs. Neither of these results was expected.

1. Stereoptic Acuity.

Since stereoptic acuity is somewhat related to visual acuity (VA)*, and since, under specific conditions of high ambient

*For example, one study (1) has shown that 5 different tests of depth perception intercorrelate positively with 11 different tests of visual acuity with coefficients of correlation ranging between .18 and .55.

illumination and low target brightness, McGraw and Enoch (7) had found a drop in VA with lengths of time during which Obrig fluid lenses were worn, a similar drop in SA with these lenses was expected in this study. The expected statistically significant differences among the mean SAs for different times of measurement were obtained neither in the general analysis nor in the analysis of the data for the Obrig fluid lenses alone. This implies that one of the following may be the case: (a) the correlation between stereopsis and VA is a spurious one, not holding for the specific stereo-task of stereoptic acuity as here defined; (b) the reported drop in VA with the lengths of time the Obrig fluid lenses were worn was statistically non-significant and/or due to specifics in the design of the study which reports it; or (c) the required conditions of high ambient illumination and low target brightness were not satisfactorily obtained in the present study.

Of these three possibilities, the last appears to be the most readily accepted. Although McGraw and Enoch (7) did report a drop in VA for an ambient illumination of 100 foot-candles and a target brightness of 12 foot-lamberts (the constants used in the present study), more convincing drops in VA were shown for higher levels of ambient illumination (300 foot-candles) and lower levels of target brightness (1 foot-lambert).

2. Spatial Localization.

It is realized that when the data for the lenses were analyzed separately there were no statistically significant differences indicated in the SLs for the six times of measurement, and, therefore, that it is not correct to present separate time trends for the different lenses. Yet, in seeking a possible explanation of the over-all trend discovered, it would be of interest to see what trends the data for the different lenses do indicate. The least-squares-fitted regression lines for the mean SLs of the four lenses at the six times of measurement are presented in Figure 2. It may be noted that the trend for the mean SL to become greater with time appears in the line of each of the lenses. This trend was greatest with the Obrig Lacrilens, next greatest with the Obrig fluid lenses, third greatest with the Dallos fluidless lenses, and least with spectacles. The trends of the Obrig fluid and the Dallos fluidless lenses were quite similar, but so also were their origins (or the initial points at which their trend lines meet the ordinate). Note also that neither of these origins was as far removed from the "correct" score of 3020 millimeters as was that of the Obrig Lacrilens. It might be said that the lines appear to be approaching the "correct" SL as a direct function of their initial displacement from that position.

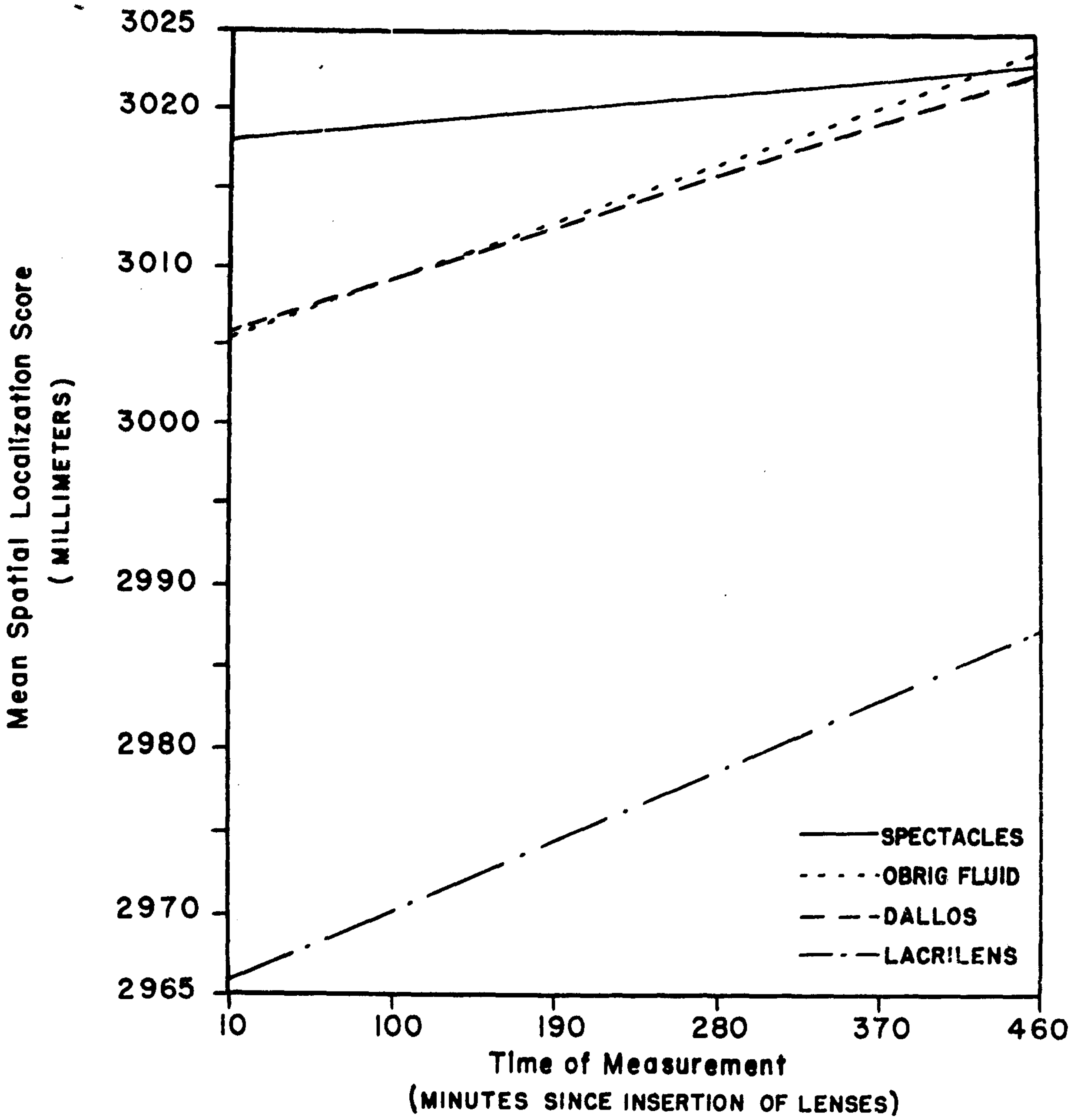

Fig. 2. Least-Squares-Fitted Regression Lines of Mean Spatial Localization Scores Obtained with Each of Four Lenses at Six Times of Measurement. (Actual target distance was 3020 millimeters. Data of Table 8.)

Accepting this observation as valid, these data suggest three hypotheses: (a) that a trend to obtain greater (or, in some cases, lesser) SLs with time will occur when contact lenses are worn; (b) that this trend will be a direct function of the absolute mean difference between SLs obtained with spectacles and with the contact lenses worn; and (c) that the direction of this trend will be a direct function of the direction of the difference (mean-SL-with-spectacles minus mean-SL-with-the-contact-lenses-worn).

These hypotheses are based on the additional assumption that the spectacles line in Figure 2, rather than the actual target distance, represents the "true" SL. Whether this is a valid assumption remains to be determined, perhaps by comparison with the SLs of non-spectacles-wearing subjects.

It should be re-emphasized that these hypotheses are only tentatively proposed as working hypotheses for a possible study concerned primarily with the changes in mean SLs occurring with time when either contact lenses, spectacles, or no optical aids are worn. Even if these hypotheses should prove somewhat valid, there would still remain not only the problem of explaining the cause of the changes in SLs with time, but also the problem of explaining the initial shifts in SLs when different contact lenses are worn. These explanations might be satisfactorily given in physical terms, e.g., some changes in refractive status occurring systematically with times of measurement. They might require the inclusion of physiological terms of explanation, e.g., some minor changes in the eye (lens, shape, etc.), which operate with the contact lenses to affect the final eye-contact lens refractive status systematically with times of measurement. Finally, they might require the inclusion of purely psychological terms of explanation, e.g., some sort of phenomenal adaptation to the false cues of linear perspective which are given, say, as a result of increased image size occurring with the use of a closer refractive plane with contact lenses than with spectacles. These examples might appear to be remote possibilities, but, as mentioned before, the authors know of no reasonable explanation for the obtained results, nor for the probable (but, in this study, statistically non-significant) differences among the mean SLs obtained at the different times of measurement with the different lenses.

B. An Evaluation of the Contact Lenses

Just as they did not enter into the preceding analyses, the Tuohy corneal lenses will not enter into this evaluation because the data obtained for these lenses were incomplete. The remaining lenses, however, will be evaluated according to the criteria established in the Introduction.

1. Stereoptic Acuity.

(The lenses are to be ranked in preferability inversely with the absolute magnitudes of the mean SAs obtained.)

No simple evaluation can be made because of the obtained "lens by subject" interaction. The lenses differed significantly in mean SA with only five of the eight subjects. Of these five, two indicated no differences between the Obrig fluid lenses and spectacles, and three indicated no differences between the Dallos fluidless lenses and spectacles. However, three subjects obtained better stereoptic acuity performances with spectacles than with Obrig fluid lenses. Three subjects obtained better performances with spectacles than with the Obrig Lacrilens, but the other two subjects performed better with the Lacrilens than with spectacles. Finally, the performances in stereoptic acuity with the Dallos fluidless lenses were worse than with spectacles with one subject, but better with another.

With this criterion, then, some of the contact lenses were better than spectacles for some of the subjects. There appeared to be no systematic relationship from which *a priori* predictions could have been made concerning which type of lens would have proven better or worse with any given subject.

2. Spatial Localization.

(The lenses are to be ranked in preferability inversely with the absolute magnitudes of the variances of the spatial localization scores obtained.)

The variances of the SLs across the six times of measurement were computed for the eight subjects with each of the four lenses. These variance estimates are presented in Table 13. Inspection of this table will reveal an apparent "lens by subject" interaction, e.g., DJF obtained his highest score with L and lowest with O, whereas, DRM obtained his highest with O and his lowest with L. Unfortunately, this apparent interaction cannot be tested for statistical significance. Had the subjects been measured over several days with each of the lenses so that there would have been several of these scores available for each lens-subject combination, this interaction could have been tested for statistical significance. Nevertheless, a simple analysis of variance of these available data was computed. A summary of this analysis is presented in Table 14. The F-ratio obtained is not of sufficient magnitude to warrant rejection of the hypothesis that the only differences among the mean variance-scores for the different lenses could have occurred by chance alone. Since the differences might have occurred by chance alone, it cannot be said that real differences exist among these scores. According to the criterion established, therefore, the lenses must be given equal evaluation.

TABLE 13
ESTIMATED VARIANCES OF SPATIAL LOCALIZATION SCORES
OF 8 SUBJECTS WITH 4 TYPES OF LENSES*

Subjects	Lenses				Total
	S	O	L	D	
DJF	883	438	4744	855	6920
JLE	578	1304	2094	259	4235
DRM	561	3353	373	1210	5497
RGA	1077	161	2504	802	4544
LFP	527	1695	962	1258	4442
JLA	182	383	629	978	2172
CJD	557	630	3189	364	4740
EJS	150	753	406	2651	3960
Total	4515	8717	14901	8377	36510

*Computed from data of Table 8.
S--Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluidless lenses.

TABLE 14
ANALYSIS OF VARIANCE OF DATA OF TABLE 13

Source of Variation	Sum of Squares	df	Variance Estimate	F*
Between Lenses	6917527	3	2305842	2.20
Residual	29363197	28	1048686	---
Total	36280724	31	---	---

*With the given df, the F associated with the 5 per cent point is 2.95.

A continuation of the present study to provide additional measurements of all the variables herein reported would be necessary before definitive answers to the questions asked could be provided.

IV. CONCLUSIONS

The wearing of some contact lenses (rather than spectacles) did alter the stereoptic acuities of some wearers. The differential performances with the different lenses were dependent, however, upon the differences among subjects. Thus, whereas a given subject might have obtained a lower stereoptic acuity score with a given type of lens, another subject might have obtained a higher score with the same lenses. Consequently, whereas one given type of lens might have been better than spectacles for a given subject, the same type of lens might have been worse than spectacles for another subject. Thus, both the differences obtained among the different lenses, and the consequent evaluations of the different lenses, were dependent upon the differences among subjects.

The wearing of some contact lenses (rather than spectacles) did result in a change in the spatial localizations of some of the wearers. Again, however, the differential performances with the different lenses were dependent upon the differences among subjects.

There were over-all differences in spatial localization scores attributable to the lengths of time the lenses (including spectacles) were worn. This trend was toward obtaining greater spatial localization scores (the target was ranged as farther) as time increased from the first series of rangings to the sixth (450 minutes after the first).

The obtained differences among the mean variances of the spatial localization scores for the different lenses were not statistically significant. This was believed at least partly due to a "lens by subject" interaction, which, although apparent, could not be tested in this study. Because the obtained differences were not statistically significant, the contact lenses could not be evaluated according to the criterion established.

V. RECOMMENDATIONS

The present study should be continued to provide additional measurements of all the variables herein reported if definitive answers to the questions asked in this study are to be obtained.

If binocular stereoscopic range finder operators are provided both contact lenses and spectacles, it is recommended that they obtain separate "ICS" settings (constant-ranging-error corrections) for the different lenses.

If binocular stereoscopic range finder operators are to be provided contact lenses, it is recommended that research be initiated to determine some method of predicting which type of lens will be best (in terms of lowest stereoptic acuity scores) for specific subjects.

The over-all spatial localization score differences attributable to times of measurement should be further investigated. The existence of such differences in normal, non-spectacles-wearing subjects should be demonstrated, and further investigation of the possible differential trends with the different types of lenses should be made.

VI. REFERENCES

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VII. APPENDIX: TABLES 15, 16, 17, AND 18

TABLE 15

STEREOPTIC ACUITY SCORES* OF JLW FOR 5 TYPES OF LENSES AT 6 TIMES OF MEASUREMENT

Lenses	Times of Measurement (Minutes since insertion of lenses)						Total
	1 (10)	2 (100)	3 (190)	4 (280)	5 (370)	6 (460)	
S	36.26	23.46	32.10	38.90	52.87	34.73	218.32
O	40.82	122.24	---	---	---	---	163.06
L	98.72	133.24	129.46	---	---	---	361.42
D	23.03	25.85	27.95	27.94	41.93	23.83	170.53
Tu	80.64	146.27	---	---	---	---	226.91
Total	279.47	451.06	189.51	66.84	94.80	58.56	1140.24

*Standard deviations of 15 rangings, in millimeters. Target distance was 3020 millimeters.

S--Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluidless lenses; Tu--Tuohy corneal lenses.

TABLE 16

SPATIAL LOCALIZATION SCORES* OF JLW FOR 5 TYPES OF LENSES AT 6 TIMES OF MEASUREMENT

Lenses	Times of Measurement (Minutes since insertion of lenses)						Total
	1 (10)	2 (100)	3 (190)	4 (280)	5 (370)	6 (460)	
S	2999	3001	3007	3011	3069	3036	18123
O	3121	3086	---	---	---	---	6207
L	3267	3163	3120	---	---	---	9550
D	3062	3083	3111	3110	3095	3117	18578
Tu	3120	2930	---	---	---	---	6050
Total	15569	15263	9238	6121	6164	6153	58508

*Arithmetic means of 15 rangings, in millimeters. Target distance was 3020 millimeters.

S--Spectacles; O--Obrig fluid lenses; L--Obrig Lacrilens; D--Dallos fluidless lenses; Tu--Tuohy corneal lenses.

TABLE 17

STEREOPTIC ACUITY SCORES* OF 8 SUBJECTS FOR THE TUOHY CORNEAL LENSES AT 6 TIMES OF MEASUREMENT

Subjects	Times of Measurement (Minutes since insertion of lenses)						Total
	1 (10)	2 (100)	3 (190)	4 (280)	5 (370)	6 (460)	
DJF	41.67	170.66	---	---	---	---	212.33
JLE	63.49	50.67	64.31	37.80	---	---	216.27
DRM	13.00	22.94	---	---	---	---	35.94
RGA	21.86	70.81	78.56	68.05	---	---	239.28
LFP	22.16	38.02	---	---	---	---	60.18
JLA	35.58	22.39	19.58	28.34	41.90	36.49	184.28
CJD	12.24	16.96	34.93	---	---	---	64.13
EJS	22.26	21.90	24.17	---	---	---	68.33
Total	232.26	414.35	221.55	134.19	41.90	36.49	1080.74

*Standard deviations of 15 rangings, in millimeters. Target distance was 3020 millimeters.

TABLE 18

SPATIAL LOCALIZATION SCORES* OF 8 SUBJECTS FOR THE TUOHY CORNEAL LENSES AT 6 TIMES OF MEASUREMENT

Subjects	Times of Measurement (Minutes since insertion of lenses)						Total
	1 (10)	2 (100)	3 (190)	4 (280)	5 (370)	6 (480)	
DJF	2991	2838	---	---	---	---	5829
JLE	3051	3046	3075	3024	---	---	12196
DRM	2944	3010	---	---	---	---	5954
RGA	3075	3041	2866	2999	---	---	11981
LFP	3042	2961	---	---	---	---	6003
JLA	2979	2989	3073	3056	2973	2987	18057
CJD	3034	3049	2930	---	---	---	9013
EJS	3030	3038	3027	---	---	---	9095
Total	24146	23972	14971	9079	2973	2987	78128

*Arithmetic means of 15 rangings, in millimeters. Target distance was 3020 millimeters.